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Shock Testing of an Endevco 8511A-20K Piezoresistive Pressure Transducer

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ARL-TN-108

MAY 1998

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5066

ARL-TN-108 May 1998

Shock Testing of an Endevco 8511A-20K Piezoresistive Pressure Transducer

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Abstract

The Defense Special Weapons Agency (DSWA) and the Navy are funding a project concept to provide information about an airframe, which includes a rocket motor, to help them meet program range and lethality requirements. The airframe is based on the Army high capacity artillery projectile (HICAP) concept, and the rocket motor is being developed. As a part of a static burn test of the rocket motor, the chamber pressure was monitored to aid in performance evaluation. It is also desirable to obtain the same chamber pressure information during the early flight tests of the projectile. Thus, it was decided to telemeter the on-board pressure data to provide information about the rocket motor burn. An Endevco model 8511A-20k piezoresistive pressure transducer was chosen to measure the rocket chamber pressure.

This report discusses a test procedure where the transducer was shocked with several thousand g's and then calibrated. A comparison of calibration values for both pre-shock and post-shock events is included. The main conclusion of the report is that the specific transducer that was tested incurred a sensitivity shift, so that the output pressure values after the post-shock event varied significantly from those of the pre-shock condition.

ACKNOWLEDGMENTS

The author would like to extend his appreciation to those individuals who helped make this report a reality. Mssrs. Charlie Mitchell and Eric Irwin are appreciated for their skills in fabricating the test fixture and operating the shock table. Mr. Daniel Bullock is recognized for performing the pressure calibration procedure on the transducer. Mssrs. Fred Brandon and Gordon Brown are also acknowledged for their guidance.

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SHOCK TESTING OF AN ENDEVCO 8511A-20K
PIEZORESISTIVE PRESSURE TRANSDUCER

1. INTRODUCTION

The Defense Special Weapons Agency (DSWA) and the Navy are funding a project concept to provide information about an airframe, which includes a rocket motor, to help them meet program range and lethality requirements. The airframe is based on the Army high capacity artillery projectile (HICAP) concept, and the rocket motor is being developed. As a part of a static burn test of the rocket motor, the chamber pressure was monitored to aid in performance evaluation. It is also desirable to obtain the same chamber pressure information during the early flight tests of the projectile. Thus, it was decided to telemeter the on-board pressure data to provide information about the rocket motor burn. An Endevco model 8511A-20k piezoresistive pressure transducer was chosen to measure the rocket chamber pressure.

The Endevco model 8511A-20K is designated as a rugged, high pressure piezoresistive pressure transducer. Figure 1 depicts the transducer and the schematic that displays the four-arm strain gauge bridge.

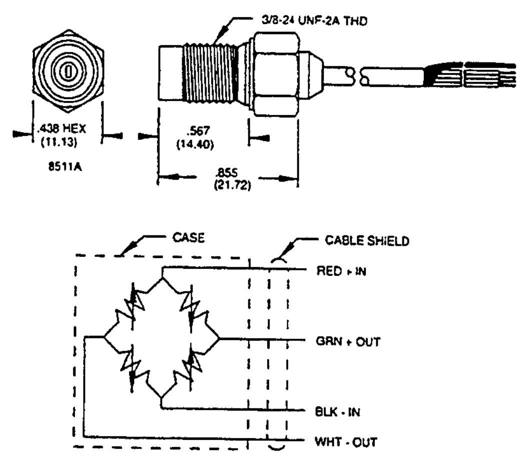

Figure 1. Endevco 8511A-20K Transducer and Wiring Schematic.

The ruggedness of the transducer qualifies it as surviving 20,000 g's for half a sine wave at 100 μs. It is to be used for high pressure applications such as studies of structural loading by shock wave resulting from explosive blasts, pulsations in hydraulic and combustion systems. The particular model that this report documents is designed to operate in the gauge mode, where the back of the diaphragm is referenced to atmospheric pressure. Table 1 lists the performance

specifications for the 8511A-20K. All specifications are at 75° F (24° C) and 10 volts direct current (Vdc) excitation.

Table 1. Performance Specifications of the 8511A-20K

Range	psig	0 to 20,000 psi
POSITIVE SENSITIVITY	mV/psi	0.025 ±0.008
COMBINED: NONLINEARITY, NONREPEATABILITY		
PRESSURE HYSTERESIS	Percent FSO RSS Max	1.5
Nonlinearity, Independent	Percent FSO Max	1.2
Nonrepeatability	Percent FSO Max	0.5
Pressure Hysteresis	Percent FSO Max	1.0
ZERO MEASURE AND OUTPUT	mV Max	±10
THERMAL ZERO SHIFT From 0° F to 200° F (-18° C to +93° C)	±Percent FSO Max	3
THERMAL SENSITIVITY SHIFT From 0° F to 200° F (-18° C to +93° C)	±Percent Max	4

2. TEST PROCEDURE

The test procedure consisted of performing a pre-shock calibration of the transducer, then shocking it with approximately 15,000 g's, and re-calibrating. The calibration entails loading the transducer with pressures in increments of 5,000 pounds per square inch (psi) (34.5 megapascals [MPa]) from 0 psi to 20,000 psi (138 MPa). Output voltage would be divided by the factory sensitivity to determine the output pressure in thousands of pounds per square inch. The transducer would then be removed from the calibration fixture and installed onto the Impac shock table. An excitation voltage was applied and the output from the transducer was monitored throughout the shock event. After the shock event, it was re-calibrated in the same fashion as before.

3. RESULTS

Table 2 displays the calibration results of the 8511A-20K transducer. The table uses a non-standard format to present pressure transducer data since the zero measured output (ZMO) readings are not included. The first shock event delivered a pulse of 10,500 g's. This magnitude of the pulse was considered to be insufficient; therefore, a second shock event was to be performed. The transducer was re-calibrated and a second shock event ensued. The magnitude of the second event was 18,510 g's. The transducer was re-calibrated after this. During this re-calibration, the transducer seal started to leak near 20,000 psi (138 MPa). The seal was tightened and another calibration took place.

Table 2. Pressure Output Data From the Calibration of the 8511A-20K Transducer

Pre-Shock Calibration			Post 10,500-g-Shock Calibration		Post 18,510-g-Shock Calibration		Post 18,510-g-Shock Calibration, Leak Fixed	
Pressure (ksi)	Output Voltage (Vdc)	Output Pressure	Output Voltage (Vdc)	Output Pressure	Output Voltage (Vdc)	Output Pressure	Output Voltage (Vdc)	Output Pressure
5	0.1279	5116	0.1402	5608	0.1405	5620	0.1404	5616
10	0.0264	10560	0.2782	11128	0.2786	11144	0.2788	11152
15	0.3915	15660	0.414	16560	0.4145	16580	0.414	16560
20	leak	n/a	0.5471	21884	leak	n/a	0.547	21880
15	0.3945	15780	0.4155	16620	0.4157	16628	0.4152	16608
10	0.266	10640	0.2798	11192	0.28	1120	0.2803	11212
5	0.134	5360	0.1407	5628	0.1414	5656	0.1415	5660

Plots of the shock pulses for both the 10,500-g and the 18,510-g shock events can be seen in Figures 2 and 3. One can see that the pulse width is on the order of 0.25 ms for both events. The smaller curve that runs through the middle of both plots represents the output of the sensor during the shock event. Figures 4 and 5 display the plots without the accelerometer data. The magnitude of the initial pulse never goes above 0.025 volt, which is only a fraction of the actual output of the sensor under a pressure load.

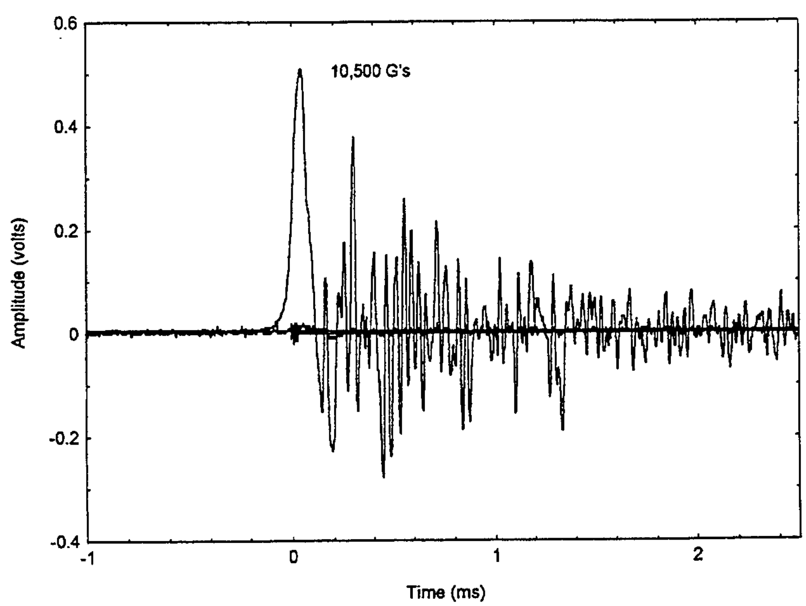

Figure 2. The 10,510-g Shock Events Pulse.

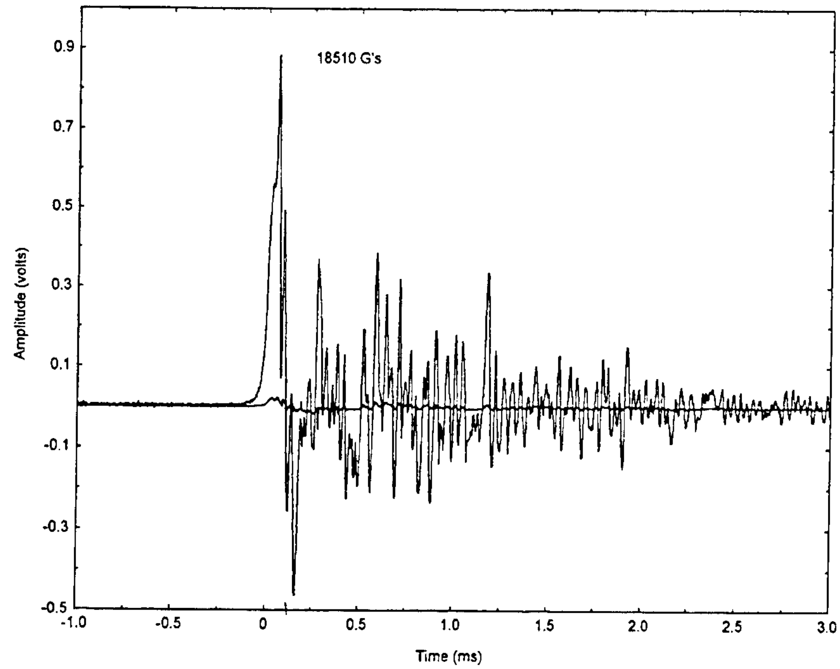

Figure 3. The 18,510-g Shock Events Pulse.

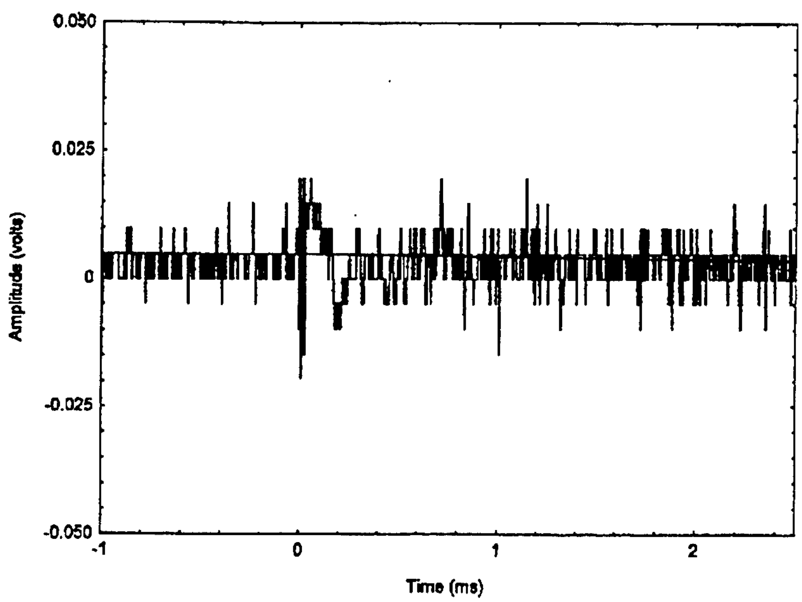

Figure 4. Pressure Transducer Output of the 8511A-20K During the 18,510-g Shock Event.

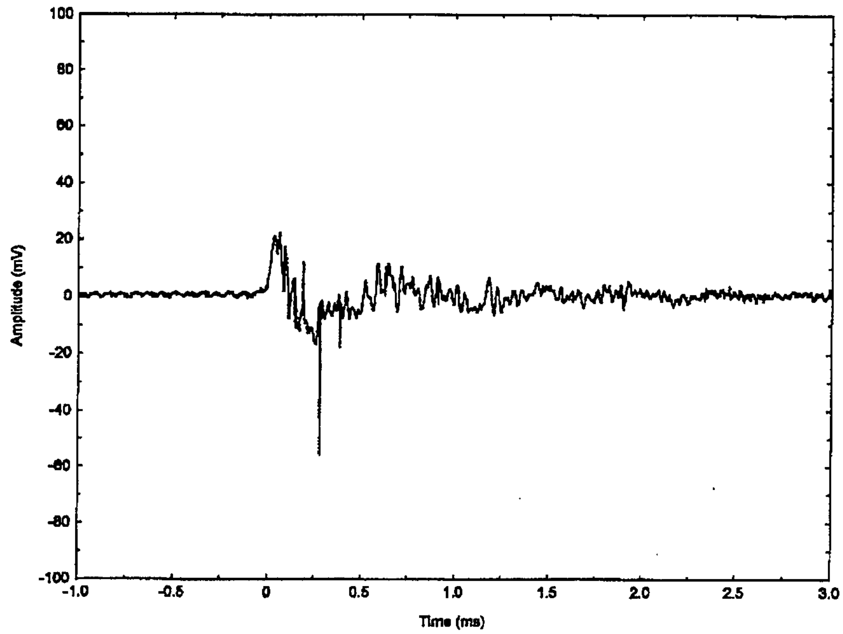

Figure 5. Pressure Transducer Output of the 8511A-20K During the 10,500-g Shock Event.

4. SENSITIVITY ADJUSTMENT

From Table 2, one can ascertain that the transducer output increases between the pre-shock and the post-shock values. In an attempt to quantify the effects of the shock loading on the transducer, this report determined new sensitivity values based on the output data. The plot in Figure 6 specifies the new sensitivities in a linear format. The x axis contains the output voltage and the y axis contains the output pressure. The graph is plotted this way to show the difference in slope between the pre- and post-shock values, the similarity in slope between the post- shock values, and to provide a means of determining gauge pressure. The plot in Figure 6 also contains the calibration data using the factory-supplied sensitivity.

A second order curve was fitted to the pre- and post-shock values. Figure 7 contains the plot of these curves. As one can see, the curves are mostly linear. This plot does not contain the calibration data using the factory-supplied sensitivity.

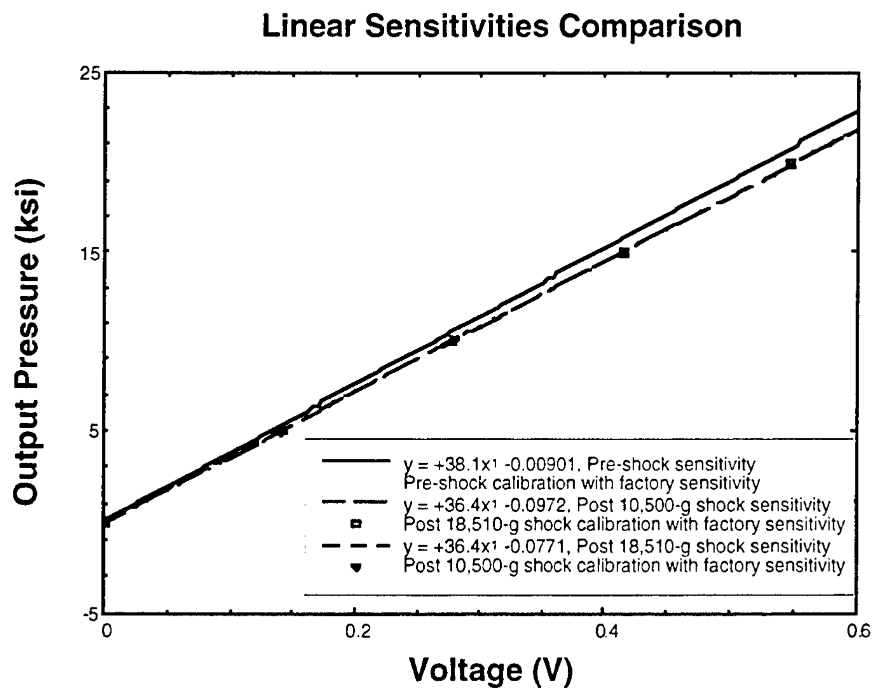

Figure 6. Comparison of the Pre- and Post-Shock Sensitivities Determined Using a Linear Curve Fit.

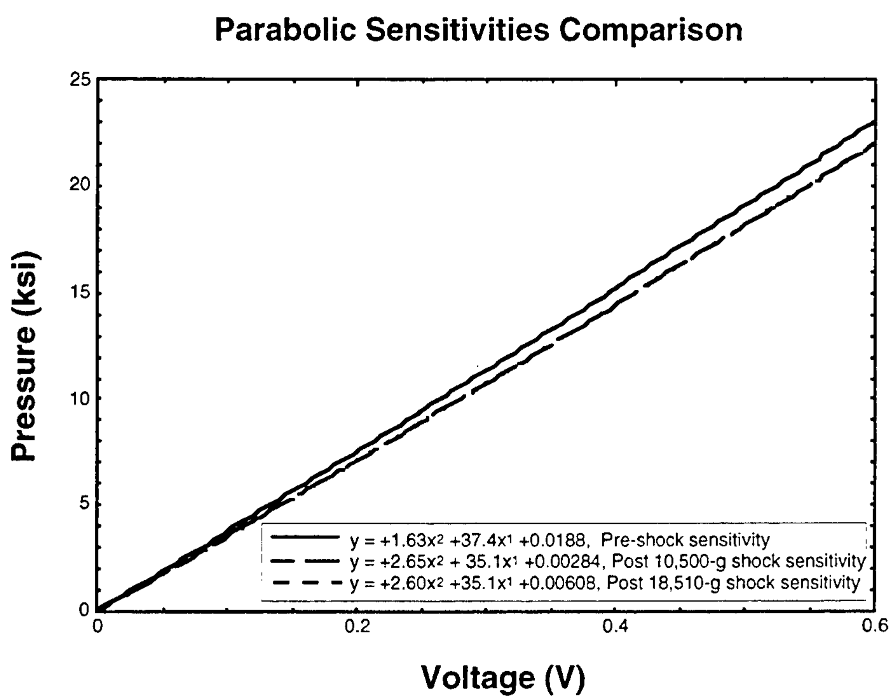

Figure 7. Comparison of Pre- and Post-Shock Sensitivities Determined Using a Parabolic Curve Fit.

5. CONCLUSIONS

Since this test was performed on only one transducer, and the gauge pressure readings differed from pre-shock to post-shock, it is recommended that further testing with more transducers be performed. However, in view of the expense of the transducers, this report makes the following recommendations. Since the sensitivity of the transducer appears to shift permanently after a 10,000-g shock, then each 8511A-20K that is to be incorporated into a high g environment should be pre-conditioned. Pre-conditioning would consist of subjecting the transducer to at least 10,000 g's and then obtaining a calibration equation of the sensitivity.

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1998	Final

4. TITLE AND SUBTITLE

Shock Testing of an Endevco 8511A-20K Piezoresistive Pressure Transducer

5. FUNDING NUMBERS

PR: 1L162618AH80

6. AUTHOR(S)

Hollis, M.S.L. (ARL)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Weapons & Materials Research Directorate
Aberdeen Proving Ground, MD 21010-5066

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Weapons & Materials Research Directorate
Aberdeen Proving Ground, MD 21010-5066

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARL-TN-108

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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14. SUBJECT TERMS

MEMS, piezoelectric, sensors, microelectromechanical, piezoresistive

15. NUMBER OF PAGES

21

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102